System Planning Guide, Electric Distribution Systems

REA BULLETIN 60-8

RURAL ELECTRIFICATION ADMINISTATION • U.S. DEPARTMENT OF AGRICULTURE

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SUBJECT: System Planning Guide, Electric Distribution Systems

I. Introduction

A. Purpose: The purpose of this bulletin is to provide general guidance in system planning for "Owners" and "Engineers" of electric distribution systems and specific guidance for REA electric distribution borrowers in preparing their long-range engineering plans. Detailed guidance for preparing construction work plans is provided in REA Bulletin 60-10, "Construction Work Plans, Electric Distribution Systems."

In arranging for engineering services for planning activities, REA borrowers should follow the procedures outlined in REA Bulletin 41-1, "Engineering Services for Electric Borrowers."

B. Explanation of Terms: For this bulletin, the following definitions of terms apply:

1. System Planning - System Planning is the careful analysis and evaluation of an electric power system, the consideration of alternative methods of meeting the electric power needs of the consumers, and the selection of the most promising of the viable alternatives for providing reliable, environmentally acceptable service at reasonable cost. System planning by REA borrowers is manifested in the long-range plan (LRP) and the construction work plan (CWP).

2. Borrower - A Borrower is an organization which borrows or seeks to borrow money from, or arranges financing through, REA for the purpose of constructing facilities or making improvements in that organization's electric system.

3. Owner - An Owner is the same as a "Borrower," except that the term "Borrower" implies a relationship with REA, while the term "Owner" implies a relationship with consultants, power suppliers, etc. The responsibilities of the owner are generally carried out by the general manager (or person with similar title) of the owner.

4. Board - The Board is the board of directors or board of trustees of the owner. The board is responsible for setting policy including final approval of the LRP.

*Comprehensive revision to bring more in line with current practices in system planning including environmental considerations, energy conservation and engineering economics.

5. Engineer - The Engineer is the individual responsible for conducting all necessary studies and preparing the planning report. Although the engineer is usually an outside consultant, the engineer may be a member of the owner's staff.

6. Power Supplier - The Power Supplier is an organization from which or through which the owner purchases wholesale power and energy. The role of the power supplier may be filled by a company, a Federal agency, or a generation and transmission cooperative (G&T) of which the owner is a member. In many cases, the owner purchases energy from more than one power supplier. In cases where all purchases are coordinated through one organization, that organization is the power supplier even if that organization has no generating capacity of its own.

II. General: There are four major functions of system management: objective setting, planning, execution, and control. System planning also has these four functions. Load forecasts and various system standards should be developed for the system (objectives); the long-range system plan should be developed (planning); the necessary facilities should be constructed in the appropriate time frame (execution); and the long-range plan should be periodically reviewed to verify its continued applicability (control). Thus system planning is a continuing dynamic process which results in a plan that is broad enough to cover all foreseeable problems and is flexible enough to allow for revision to cover unforeseen problems. Some plans may require revision within 6 months of completion while others may require no revision in 10 years of use. Regardless of the date of preparation, the long-range plan being used should be appropriate and should consider the latest information available.

Many of the old adages and rules-of-thumb concerning system planning have ceased to be relevant, while many others are more material than ever. It is the responsibility of the system planner to sort out available information to determine the best approach for the individual system to use in attempting to provide adequate capacity in a reliable, economical, environmentally acceptable manner.

Long-range system planning calls for analysis of the system far beyond the present design requirements. System demand for the plan should be large enough and the time frame chosen should be long enough to require replacement or increase in capacity of each major facility of the system. Loads less than this will usually be inadequate to test the validity of the planning hypotheses. In several regions of the country, G&T cooperatives arrange for all members to update long-range plans at one time to facilitate G&T planning.

A long-range plan provides a guide for developing the existing system toward the capacity level which will be required at the end of the plan period, through construction of new facilities and expansion of existing facilities at appropriate times. By using this approach, any interim change or system addition will be compatible with the needs of the final study level.

Although each system's long-range plan will be different, all plans should have the following basic provisions:

Orderly system development to minimize waste due to early obsolescence or inadequacy of facilities.

As much as possible, system expansion investment that is in step with expected load growth.

Maximum use of opportunities to improve the quality of service at minimal cost.

Provision for future decision to incorporate appropriate developments in equipment design and application.

A combination of the best alternatives considering economics and system reliability.

III. Planning Functions: System planning can be divided into five distinct tasks, as follows:

A. Compilation of Basic Data: Basic data should be maintained and continuously updated to facilitate the evaluation of newly proposed alternatives throughout the long-range plan period.

B. Review of System Requirements: The existing system should be analyzed to ascertain its ability to serve present and projected requirements. The planner should determine what additional capacity is needed and what facilities will need replacing during the long-range plan period. This information will aid in the judicious selection of alternatives.

C. Preparation of Exploratory Long-Range Plans: Once the system requirements have been determined, various alternative plans can be formulated which will satisfy these requirements.

D. Plan Selection: By careful application of present worth analysis or some other valid economic analysis procedure, the engineer can select the best plan for the projected requirements. It is extremely important that each alternative evaluated provides for minimum requirements of quality of service, environmental acceptability, and system capacity at each level of the long-range plan period. This can be accomplished by combining the various facilities needed (for each alternative) to maintain the service quality and capacity specified. Some alternatives may provide a temporary excess of capacity. This excess should be permitted only if it justifies itself through reduced overall construction costs or reduced losses.

E. Preparation of Construction Work Plans: At least once every two years, the long-range plan should be reviewed in light of actual system developments to determine whether the LRP needs to be revised or updated.

A two-year work plan should be prepared and, where practical, a comparison should be made to determine which of the facilities demonstrated to be necessary in the LRP will be most appropriate to install during the immediate work plan period.

IV. Details of System Planning: Although actual planning procedures followed by each planning engineer may vary in detail from those described in this guide, for the sake of uniformity system planners should make an effort to follow the format presented here. The REA field engineer is available to assist the owner and the planning engineer in developing a useful and acceptable long-range plan.

A. Preliminary Conference: The owner should arrange a preliminary conference with the engineer. The REA field engineer and the power supplier should be given the option of also attending. At this conference, the owner should provide the planning engineer with the following basic data:

1. Up-to-date copies of circuit diagrams, one set of detail maps showing the existing system, and the latest REA-approved PRS.

2. Local planning board maps or other data regarding existing and projected (a) population and load density; (b) zoning and land use; and (c) areas known to be environmentally sensitive.

3. Location of existing and expected future large power and special loads. (Where heavy irrigation is involved, the owner should furnish the engineer with an REA-approved irrigation study.)

4. Results of all recent voltage and current investigations, phase balance and sectionalizing studies, and information on power factor of the system and of distinct areas of the system.

5. All pertinent data relating to existing and planned sources of power together with present and projected wholesale power rates for both existing and planned power sources.

6. A copy of the latest Rating Review Summary, REA Form 300, (see REA Bulletin 161-5, "Electric System Review and Evaluation") and cost summaries for recent construction of various types of facilities in the existing system and other records of operations on which cost estimates may be based, latest available data concerning fixed charge rates (existing and projected), and information on load factors. (Fixed charge data should include depreciation rates, taxes, insurance, interest, and operation and maintenance expenses for the various types of facilities in the system. If the owner is a member of a G&T, the G&T's fixed charge data should also be provided.)

7. A copy of the owner's Energy Conservation Plan along with information on any existing or proposed load management system.

8. Any other pertinent data related to the services to be performed by the engineer.

Much of this information may already be in the possession of the engineer or available from billing files. The engineer should assist the owner in establishing and developing a procedure for updating this basic data file which will be useful in future planning activities. The engineer should also recommend methods of and locations for voltage and current investigations and methods for extracting the necessary load data from computerized billing files. This load data is invaluable for load forecasts, rate analyses, and long-range financial forecasts.

Since the long-range plan will be no better than the data on which it is based, the engineer should review the basic data for adequacy. The engineer should request any necessary additional data and recommend improvements in programs used for regular data collection and record-keeping. This will insure availability of sound data for continuing system planning activities.

B. Analysis of Existing System: The analysis of existing system (AES) may indicate where alternate proposals are most likely to be economical and provide insight into the development of a practical transition from the existing to the proposed long-range system.

While the construction work plan (CWP) covers many of the same topics as the AES, the AES should approach the subject from the standpoint of major policy needs while the CWP should approach the subject from the standpoint of necessary changes in facilities within the context of established policy. Therefore, even if a CWP has recently been completed, an AES should be prepared for the LRP.

The following items should be of primary concern in the analysis:

1. System Growth Patterns: Even a system which anticipates zero or negative load growth must prepare for the possibility of some load growth. It will be necessary for the engineer to determine how the system load will be distributed among the various regions of the system. To predict with reasonable accuracy the requirements of these various regions of the system, it is necessary to have information on the relative number of consumers, load per consumer, and total load for various regions of the service areas in the present and the projected system. Data should be collected for small enough unit areas to indicate boundaries of larger load density regions. Section units of one square mile should usually be appropriate. Although many systems already use a similar system based on feeder sections or substation areas, this arbitrary area basis shows where the load is independent of the location of existing facilities and thus where facilities should be. As this information will be valuable for development of the long-range plan, and in other planning activities, it will be well worth the time required to set up a coding system similar to the following.

A copy of the system map can be overlaid with an arbitrary grid. (The one-square-mile section area may be appropriate for most systems; however, a smaller or larger unit area may be more appropriate for some systems.) Each consumer can then be identified in the billing records as to the number of the grid section in which the meter is located. The number of residential, industrial, and commercial consumers and total energy for the peak month can easily be calculated for each unit area and recorded on the system map for each grid square. In many cases, the above load data can be validated by spot comparisons with voltage and current readings. While the one-square-mile sections are too small to be meaningful themselves, the resulting system map will show contiguous areas of relatively high, moderate, and low density. (See Appendix III.)

Additional valuable regional growth information may be obtained from local land use planning organizations, chambers of commerce, etc.

2. System Capacity Relative to Existing Load: The existing system should be analyzed first to determine how well the existing facilities are meeting the present needs of the system as indicated by metering and billing data. The areas of the system where it is difficult to achieve acceptable levels of system performance should be identified. This information, along with the "System Growth Patterns," should indicate the areas where the most drastic or immediate action is needed.

3. System Capacity Relative to Future Load: In addition to such considerations as excess transformer capacity in existing substations, the engineer should review the space limitations for increasing the capacity of present substations. Is there capability for installing additional feeders at existing substations and along highways and existing rights-of-way? Which areas of the system are voltage limited? Which are thermally limited? How old are the existing facilities? Will some facilities need replacement even if not upgraded?

4. System Performance: By comparing the performance of various areas of the system, the engineer can locate those sections which will benefit from more drastic improvement efforts. Analysis of the following conditions will indicate the level of performance of the existing system:

   a. Voltage Levels and Current Balance: The results of voltage, current and power factor measurements, and voltage drop calculations for critical feeder points should be reviewed. See REA Bulletins 45-1, "Guide for Making Voltage Drop Calculations," 161-7, "Guide for Making Voltage Measurements on Rural Distribution Systems," 161-8, "Voltage and Current Investigations," and 161-9, "Guide for Making Current Measurements on Rural Distribution Systems," for information on conducting this review.

b. Service Reliability: A service reliability study will indicate areas of the system which need special attention and may even indicate the general type of work which will be most cost effective in correcting such service deficiencies. Service interruption records for the preceding five-year period should be examined with particular attention given to interruption averages for each distribution feeder and for each substation. These averages will indicate major differences in service reliability in various regions of the system. This information should be compared to the service reliability standard set by the system management (see REA Bulletin 60-7, "Service Reliability"). Frequent and/or long duration outages should be noted and the probable cause determined. If the power supplier is responsible for an excessive amount of the outage time, this should be noted.

c. Energy Losses: Energy losses are more important than they have ever been. Through review of operating records, the energy losses in kWh per year and in percent of sales levels should be determined for substation and metering point areas throughout the system. These loss levels should then be compared with the guidelines presented in REA Bulletin 45-4, "Distribution System Energy Losses." The probable cause of any excessive area losses should be determined and noted for possible corrective measures.

d. Operation and Maintenance (O&M) Expenses: O&M expenses on a system are dependent on such factors as cost of labor, load density, and number and size of facilities. By analyzing the O&M expense allocations on the system, those items with exceptionally high operating expense rates can be properly identified and methods of reducing those expenses evaluated. O&M items which appear not to be receiving adequate funds should be compared with outage and inspection reports to ascertain if additional emphasis is required.

Excessive O&M costs on an individual portion of the system may be the most obvious indication of prior planning deficiencies.

Based on the analysis of the existing system, the planning engineer should make recommendations for improving system performance and increasing system capacity for expansion. In addition, the planning engineer should recommend more detailed measuring or recordkeeping for those areas where data is inadequate. The basic data and analysis of the existing system should be prepared in draft form for use during the intermediate conference. Later the final report should be made a part of the system planning report. (See Appendix I.)

C. Intermediate Conference: When the engineer has completed the analysis of the existing system, the owner should arrange an intermediate conference to discuss the study (to date) and the direction in which the study should continue. The conference should be attended by the

manager, any other appropriate system personnel, and the engineer. The REA field engineer and a representative of the power supplier should be given the option of attending. The conferees should review the analysis and the basic data for adequacy, and determine what, if any, additional data is needed and the method to be used in obtaining it. Basic planning criteria should be established for the long-range plan at this conference.

D. Criteria for Long-Range System Planning: Since the long-range plan should be used to guide the development of the system for several years, the criteria used in formulating the plan is of utmost importance. The owner has the primary responsibility for selecting the planning criteria. The selection should be based on sound judgment with suggestions and recommendations of the planning engineer and the REA field engineer. The following brief discussions suggest the planning criteria that should be established:

1. Long-Range Demand Level: The long-range demand level should be of such magnitude to require capacity increases in major system components. The plan will thus allow comparisons of alternate ways of providing for increased service in various parts of the system and in the system as a whole.

   The effectiveness of the long-range demand level is generally more dependent on its relative magnitude than the time frame. In some critical situations, however, the exact time frame will determine which of two alternatives will be more economical. In such cases, more precision should be used in establishing the time frame during the plan selection phase.

2. Area Load Density and Growth Potential: Very seldom will a system have uniform load density and growth potential. However, by analyzing the system load and population maps prepared as suggested in Section IV.B.1., and land use plans for the system area, those regions with similar requirements can be located and grouped for similar handling. Estimates of growth potential and realistic maximum energy usage per consumer should be incorporated to project ultimate area demand levels. Thus the total system demand and the average growth rate of the entire system will be determined by the demand and growth rate of the various portions of the system.

3. Special Loads: Depending on the size of the system, loads with more than a predetermined size (100-1000 kVA) of connected transformer capacity and concentrations of small pumping and irrigation loads should be identified by size and location in the system records. These special loads will require special consideration with regard to their demand on the system. Management should analyze the special loads presently served to determine the kW size for each of those to be considered in the LRP. Those special loads that management is reasonably sure will be served by the long-range system should be provided for in the plan. Other special loads, not supported by reasonably firm data can be designed for on an individual basis as they develop.

4. Service Reliability: A service reliability standard provides a basis on which management can evaluate system performance. The importance of service reliability should be reflected in the long-range system plan. Because of wide differences in operating conditions and local requirements, REA does not attempt to specify a service reliability standard for all systems. However, each borrower should adopt a standard which will serve as a goal in the development of its system.

   The five consumer hours per consumer per year interruption rate used for loan applications should not be considered a goal. Rather, system goals should be nearer one hour for suburban and two hours for rural consumers. Furthermore, it should be recognized that except during truly unusual major storms, consumers are not concerned with the source of an interruption. Whether the power is off only for their individual transformer or because of a power supplier's interruption makes little difference to the consumer. Thus all sources of interruption should be considered for possible improvement in service reliability.

   Interruption rates should be further compared for each individual part of the system to determine the consistency of the level of service reliability. REA Bulletin 60-7, "Service Reliability," contains information and guidance in conducting a service reliability analysis and setting service reliability standards.

Any additional criteria which management is considering should be carefully evaluated for its benefit to cost relationship and should be discussed thoroughly with the planning engineer and the REA field engineer.

E. Design Considerations: The system should be designed to provide adequate and reliable service at reasonable cost to all consumers. Many decisions made in formulating the long-range plan will affect or be affected by the system design. It is therefore important that the system planners are cognizant of these effects. The following discussions present items to consider in the design of the system:

1. Power Sources: Planners should carefully consider the capacity and adequacy of all existing and prospective power sources. If the source is unable to supply the necessary quantity of power for its area, if the interruption record is poor, or if voltage levels will be inadequate, then alternative sources of power should be investigated. If the owner is a member of a G&T, these problems should be taken up with the G&T staff and/or the board. Interruption data should be recorded and evaluated on a regular basis for all existing power sources and interruption rates for prospective sources should be estimated based on records for facilities with similar characteristics.

   The Public Utility Regulatory Policies Act of 1978 (PURPA) requires that electric utilities allow their consumers to interconnect privately owned generating equipment and requires the utilities to purchase power and energy from such facilities

at reasonable prices. Thus the owner should establish a policy covering purchase of power from consumer-owned solar, wind. diesel, small hydro and co-generation installations. The owner should also consider the possibility of installing such facilities of its own as compared to use of energy purchased from conventional generating facilities, in accordance with the present national effort to conserve energy.

Differences in cost of power between alternative wholesale power sources should be considered (although it is usually unwise to design or redesign a system to take advantage of a temporary condition). Consideration should be given to the investment required in facilities to utilize the power and the availability of sufficient power when and where it is needed. The nearest or cheapest source of power need not be selected if, overall, another source can be shown to be more appropriate. If a change in power supplier is indicated, the REA field engineer should be consulted regarding the power supply survey requirements.

2. Transmission Lines: Although the long-range plan is not the place for detailed design of transmission lines, attention given to the proper aspects of transmission line planning may avert serious problems later. It is extremely important that the distribution system's LRP is coordinated with the LRP of the power supplier regarding transmission planning. Whether the transmission lines are owned by the distribution system or the power supplier, planning should be approached on a "one system" concept. Thus excessive costs for transmission facilities cannot be justified by minor savings on the remainder of the system. The converse is also true that excessive distribution plant should not be constructed simply to avoid transmission construction.

   The following factors should be determined for all transmission lines in the long-range plan:

   a. Approximate Line Length: Line end points and future extensions should be approximated.

   b. Voltage Class: The voltage class of the transmission line should generally be determined by the voltage of the line to be tapped. Occasionally an exception is justified due to superior reliability for a small increase in cost or where total benefits outweigh the added cost of the alternative.

   c. Conductor Size: Transmission conductors should be tentatively sized based on economic studies taking into consideration line losses, present and future power requirements, cost of upgrading the line when the conductor is no longer adequate, and the cost of carrying excess capacity until it is needed. Costs of stocking and hardware standardization should also be considered where a new conductor size has been indicated by other factors. For higher voltage transmission projects, conductor size is generally finalized before actual engineering and construction occurs.

d. Environmental Concerns: Obvious environmentally sensitive areas along the corridor proposed for line routing should, if possible, be avoided. Also, where possible, right-of-way requirements should be held to a minimum.

e. Stability and Load Flow Characteristics: At least a rough check of stability and load flow characteristics should be made and if it indicates the need, more extensive studies (computer load flow, stability and transient network analyzer studies) should be performed. In some cases, load flow studies will influence the location and timing of major substation additions. In that case, the engineer should coordinate with the system manager for these studies. REA Bulletin 62-6, "An Overview of Transmission Studies," provides guidance on conducting these studies.

f. Transmission System Configuration: The economy of radial feed substations should be weighed against the increased reliability of loop feed substations. The system applicability to each should be carefully considered.

REA Bulletins 62-1, "Design Manual for High Voltage Transmission Lines," and 62-5, "Electrical Characteristics of REA Alternating Current Transmission Line Designs," provide information on transmission line design which will be helpful in system planning. Transmission facilities which are well planned will provide high continuity of service, long life of physical equipment, and safe operation at relatively low overall cost.

3. Substations: A major decision to be made in long-range planning is the number and size of substations needed to provide services to the system. Neither too many nor too few substations should be provided for. If possible, the cost and reliability of additional substations should be weighed against the cost and reliability of other alternatives. Decisions as to the exact location of substations should be reserved for consideration in the construction work plan, with only relative locations (consistent with the appropriate number and size of substations) considered in the LRP.

4. Primary Distribution Lines: Whether primary lines are constructed overhead or underground, effective planning is needed to avoid premature obsolescence of facilities. REA Bulletin 60-9, "Economical Design of Primary Lines for Rural Distribution Systems," gives guidance in selection of conductor size, circuit voltage and number of phases for economic construction and operation of new and converted overhead distribution lines. REA Bulletins 61-3, "Underground Rural Distribution," and 61-15, "Selection and Application of Underground Rural Distribution Cable," discuss underground facilities.

It is necessary to consider many factors in determining whether distribution line construction should be overhead or underground. Overhead lines generally involve lower construction costs and

ease of maintenance. Underground lines generally have less environmental concerns, are less affected by storms, have lower line losses and less voltage drop problems for a given ampacity. However, underground lines are sometimes subject to certain technical problems and high replacement costs. The following discussions will provide guidance in developing distribution line standards:

a. Voltage Level: Distribution lines should meet the voltage standards given in REA Bulletin 169-4, "Voltage Levels on Rural Distribution Systems," or any more stringent local regulations. Generally, maximum voltage drop at extremities of feeder taps and minimum power factor are specified. Digital computers can be used for voltage drop calculations by developing a program from the procedure outlined in REA Bulletin 45-1, "Guide for Making Voltage Drop Calculations." Often, the entire system model can be kept in the computer (or on tape, etc.) and frequent use made of it to check system needs and capabilities. The price per computation will generally be quite small.

b. Service Reliability: It is not always possible to use the most economical system configuration (conductor size, line voltage and numbers of phases) and still meet system standards for voltage level and service reliability. It is generally necessary to trade-off between reliability and economy. Service reliability should, therefore, be improved in that portion of the "line of supply" to the consumer where it can be done at least expense in order to make up for those places where improvements in reliability are too costly. Estimates of the incremental improvement in service reliability can be developed from experience with similar facilities. REA Bulletin 60-7, "Service Reliability," discusses the factors which affect service reliability.

   Generally, shorter lines from smaller substations will lead to higher reliability, However, line reclosers and sectionalizers will improve reliability to some extent on long radial lines. Multiple substation transformers (four single-phase or two three-phase units) and multiple feed transmission can also help as can the use of a mobile transformer. The decision on the size and number of substations needed in the long-range plan should be made based in part on system experience with the source of interruption hours and the cost of improving reliability in those areas.

c. Conductor Size and Phasing: In spite of the high cost of rebuilding lines, and the careful planning done in the past, it will often be necessary to increase the capacity of existing sections of distribution line. Before deciding to rebuild a line, however, careful consideration should be given to a number of factors including:

(1) Age of the Line: If the line is quite old and will need replacement by the end of the long-range plan period, then rebuilding with increased capacity may be a better way of obtaining increased capacity than building an additional line. In some cases, considerable research may be needed to determine the age of various lines. However, rough estimates of age will be adequate for these purposes.

(2) Routing: Since the rebuilding operation will probably require replacement of most if not all poles, a different route may now be more desirable than the original one. For example, a line originally constructed on a right-of-way remote from the highway might be moved adjacent to the highway providing more economical maintenance of both the line and the right-of-way, with minimal reduction or even net increase in reliability. Environmental considerations, of course, may preclude any rerouting of lines in a given area. The alternatives should be considered carefully before a decision is made to reroute a distribution line.

(3) Plans for Other System Additions: If, within a reasonable time, a new substation or an additional feeder from the existing substation will tend to eliminate the benefits of rebuilding, the condition can probably be corrected with some temporary measure until the other system improvement is completed.

In general, line conversion should be considered when the annual savings in losses equal the annual fixed costs of conversion construction. Naturally, transferring of load to other lines will reduce the amount of savings possible; however, with the wholesale cost of energy increasing, this point will be reached sooner than it was when power costs were decreasing. Furthermore, when a conversion is needed, added savings and benefits of energy conversion may result from use of an even larger size conductor than the minimum size which can be economically justified, since energy costs and cost of future improvements will continue to rise while the cost of completed improvement will be fixed. Such a choice should be made cautiously, however, with the aid of economic analyses. (See Section V.B.3.)

d. Routing: When new distribution lines are needed, the routes should be chosen, where feasible, to be along improved roads to facilitate operation and maintenance and to provide maximum opportunity to serve existing and potential consumers.

e. Voltage Class: Where it is necessary to change the system standard distribution voltage class, consideration should be given to all standard distribution voltage classes. Frequently only one alternative voltage will be feasible;

however, occasionally a voltage class which was not considered at first will provide greater long-term benefits. After a conversion has been made, a further conversion will not be feasible as many of the costs associated with either change would be incurred a second time with a smaller off-setting savings.

REA Bulletin 60-13, "Conversion of 7.2/12.5 kV to 14.4/24.9 kV Distribution," provides guidance in determining the order and method of conversion, some of which will be useful for economic comparisons needed in evaluating these alternatives in the long-range study.

5. Voltage Level and Power Factor Control: Virtually all systems use voltage regulators to maintain adequate voltage levels at extremities of distribution lines until major improvements can be justified. Shunt capacitors have generally been used primarily for power factor improvement, however, they also assist in voltage regulation.

REA recommends that some form of voltage regulation be used in substation and distribution metering points (unless a metering point has a well regulated supply). REA further recommends, that in general, only one voltage regulator should be installed on the distribution line between any consumer and the substation. These are recommendations and not hard-and-fast rules.

The LRP should provide for maintaining a maximum voltage drop of 8 volts, regulated in the initial stages and unregulated in the final stages. Where more stringent requirements are imposed by local authorities, they must, of course, take precedence.

REA Bulletin 169-27, "Voltage Regulator Application on Rural Distribution Systems," discusses factors to be considered in the application of voltage regulators, including such things as line drop compensation which can improve operation and/or extend the range of voltage regulators.

Consideration should also be given to the voltage regulating capabilities of shunt capacitors. In addition to power factor control which may reduce power costs, capacitors will provide some energy conservation and low cost, low maintenance voltage regulation. Guidance in application of shunt capacitors is provided in REA Bulletin 169-1, "The Application of Shunt Capacitors to the Rural Electric System."

V. Development of the Long-Range Plan:

A. Requirements of the Plan: The long-range plan is a management tool and a guide for the following:

1. The most practical and economical means of serving a growing load while maintaining high quality service to the consumer.

2. An outline for system growth in terms of major facilities, demand levels and associated costs.

3. An indication of future system costs for financial planning and decisionmaking.

Due to the nature of the long-range plan and the approximations made in various projections, detailed calculations are seldom cost effective for analyzing alternative plans.

B. Major Steps:

As the plan should be based on the planning criteria, design considerations, basic data, and the analysis of existing system, little can be done regarding specific alternatives until after the intermediate conference. However, certain existing conditions will be evident as problem areas requiring that alternative configurations be considered for later economic comparison.

After the intermediate conference, the following major steps should be taken to develop the long-range plan:

1. Exploratory Plans: The demand level established for the long-range system should be large enough to permit the engineer to explore many possible plans and system configurations. The planning criteria and design considerations established in the intermediate conference should be followed in developing each exploratory plan. Each plan should make maximum economical use of existing facilities or correct a major problem while satisfying the planning criteria to the greatest extent possible. System standards for voltage, service reliability, etc., should be maintained by those facilities installed during the transition from the existing to the long-range system. Generally, only major items such as substations, transmission lines, and distribution feeder main lines should be considered. The following are typical considerations for exploratory plans:

    a. Increase the capacity of existing substations and heavy up the distribution lines.

    b. Install additional substations, effectively shortening the distribution lines.

    c. Install loop feed transmission lines to substations.

    d. Install radial feed transmission lines to substations.

    e. Convert areas to a higher voltage class.

    f. Replace metering points with transmission lines and substations.

    g. Install additional feeders from existing substations.

The engineer may wish to consider other approaches to expand the existing facilities to serve the long-range load. In most cases, it will be possible to establish two or three preferred exploratory plans without the time-consuming task of laying out and comparing a large number of designs. If the criteria prove too restrictive, causing the exploratory plans to be unreasonable, the engineer should inform management giving recommendations for modifying the criteria.

Each exploratory plan should consider the major facilities required to provide a transition from the existing to the long-range system. The plans should be expressed in terms of capacity, cost, and estimated years for expenditures. A list of required major system improvements should be prepared showing their respective costs and the projected years in which they will be needed for each exploratory plan.

Although each exploratory plan may not be able to have the same capacity each year of the study period, each alternative must provide similar reliability and capacity at the long-range load level. For certain facilities, capacity constructed before it is actually needed, will pay for the additional ownership cost from savings realized by reduced losses and avoidance of cost escalations. Other facilities, however, may not provide these benefits and should not be constructed before they are absolutely necessary.

2. <u>Comparison of Plans</u>: The following are typical of the comparisons and considerations which should be made in connection with developing the exploratory plans. This should not, however, be construed as limiting consideration to these examples.

   a. Although an existing distribution metering point might be used in the long-range system to serve the increased load if the size of the conductor on the main feeder is increased, the costs and benefits of such a plan should be compared with those of a plan involving the construction of a transmission line and substation to replace the metering point. Reliability of service should be examined for each of the plans being compared.

   b. Although existing substations might be used in the long-range system to meet the increased system load through the conversion of 12.5/7.2 kV distribution lines to 24.9/14.4 kV, the costs and benefits of such a plan should be compared with those of an exploratory plan involving the construction of additional substations and transmission lines. All foreseeable costs associated with converting to the higher voltage level should be considered in the comparison, including increased costs of transformers for connecting new consumers and for changing transformer installations for existing consumers. Such costs as may result from possible changes in code requirements should not be considered unless they can be documented.

Reliability of service should be examined under each of the plans being compared. Normally, establishing new load centers would effectively shorten the distribution lines, whereas, voltage conversion may result in an effective sacrifice in reliability. Consideration should therefore be given to methods of obtaining an offsetting increase in reliability, for example, two three-phase transformers in the substation, four single-phase transformers, or a mobile transformer. The incremental increase in reliability and cost of each alternative should be evaluated. Consideration should also be given to such possibilities as loop-feed trasnmission to the substation or more sophisticated distribution line sectionalizing to improve the reliability of the supply. Thus, the exploratory plans to be compared can be made to have similar reliability levels.

c. Where it is deemed necessary to abandon a delivery point (distribution or transmission) because of excessive outages attributable to the power supplier, the engineer should present supporting outage data plus any other information available which will justify replacing the metering point.

d. If an exploratory plan calls for the construction of transmission facilities because the existing power supplier's facilities are inadequate or unreliable, the engineer should, in addition to making comparative economic studies, present data to show evidence that the existing power supplier has been contacted and has refused to correct the inadequacies. The point of delivery for the proposed transmission facilities will need to be a reliable power source. If a change in power supplier is involved, information should be furnished to show that the new power supplier's facilities are adequate and reliable. The savings, if any, resulting from the change in wholesale cost of power and increased reliability of service, gained through construction of the transmission facilities, should be commensurate with the additional investment in facilities necessary to make the change, i.e., this should be the most beneficial means of providing the reliability or capacity needed.

   Any change in power supplier for a portion of the system load will have power survey implications (see REA Bulletin 111-3, "Power Supply Surveys"). Such a recommendation should be discussed with the REA field engineer.

e. If a plan calls for the construction of transmission facilities because the power supplier will not provide bulk power at or near the load centers, the benefits to be gained by building directly to the load centers should be examined in light of the additional expense of constructing and operating the transmission facilities and the costs and disadvantages of long distribution lines from the alternative substation to the load center.

Each exploratory plan should be based on power sources that the engineer and system's management are reasonably sure will be available. Every attempt should be made to persuade the existing power supplier to furnish adequate and reliable sources of power where they are needed.

Where necessary, alternative recommendations should be made based on savings that would be realized if the power sources could be obtained closer to the load centers. These alternative recommendations should be provided only for those cases that appear reasonable and practical.

3. Plan Selection: The development of the LRP should not be restricted by the limitations of the existing system. Although it must be recognized that there are certain inherent benefits associated with the continued use of installed facilities, alternative proposals should be adopted if the projected benefits from the change will exceed the cost of the change. Several factors must be considered in selecting the recommended long-range plan:

   a. Economic Analyses: The primary concern in plan selection will generally be for comparative economics. In evaluating alternative exploratory plans, it will frequently be necessary to compare plans with widely varying time/cost distribution, i.e., one plan may have high first cost and another plan may have high annual costs. Simply selecting on the basis of lowest first cost or lowest annual costs may eliminate the alternative which would provide the best service at the most reasonable cost to the consumer. There are numerous methods of performing economic comparisons: present worth, annual costs, capitalized annual cost, minimum revenue requirements, etc. Any good textbook on engineering economics will explain several of these methods. Whichever method is used, the following factors should be considered:

      (1) Time Value of Money - The dollars spent this year are worth more than the dollars spent next year.

      (2) Inflation - Labor and material costs are increasing and will most probably continue to rise.

      (3) Specific Fixed Costs of the Owner - The owner's system has historical fixed charge rates provided as basic data. These rates may change with replacement of older facilities (decreased O&M, increased taxes, etc.).

      (4) Energy Losses - It should be recognized that not only will the annual kWh losses increase with system load growth, but the cost of those kWhs will most likely increase.

   b. Sensitivity Analysis: When the economic comparison indicates the costs of two alternative plans are within 10 percent of each other, a sensitivity analysis should be performed to

verify the validity of assumptions. Increase in interest, inflation, energy losses, growth rate, etc., should be considered to determine if the selected plan is likely to become infeasible after the owner has become committed to it. The results of the economic analysis and sensitivity analysis should be presented in tabular form and included in the LRP report.

c. <u>Other Factors</u>: If two plans are still close after analyzing their sensitivity to overall cost changes, other factors should be considered:

(1) <u>Energy Conservation</u> - Although energy losses were considered in the economic analysis, if two plans will cost roughly the same amount but one plan will result in a net energy savings, that plan should be given a priority credit.

(2) <u>Excess Capacity</u> - Although each plan must provide the minimum capacity required to serve the projected system load, one plan may provide more excess capacity at the end of the evaluation period. In that respect the plan with excess capacity is superior.

(3) <u>Service Reliability</u> - Although each plan must provide for minimum levels of service reliability, one plan may involve inherently better service reliability. In that respect, this plan is superior.

(4) <u>System Labor Costs</u> - If a system has labor costs below the national average, a more labor-intensive alternative may be appropriate. However, if additional labor is not available in the community, a large construction program will require use of outside contractors for a larger percentage of the work to be done thus increasing the system's average labor costs.

(5) <u>Flexibility</u> - One plan may be superior in its capability of further expansion beyond the long-range plan level while the other will require radical changes in policy at that point. On the other hand, the plan which defers major expenditures has the value of increased flexibility to take advantage of future developments.

(6) <u>Solution of Chronic Problems</u> - One plan may eliminate a problem which has given management continuous headaches while the other plan does not. This should also be considered.

The techniques of cost benefit analysis may be helpful in evaluating alternatives based on the above factors. A good textbook on cost benefit analysis will explain the procedure.

Tables of both fixed and variable cost rates for the system should be prepared and included in the exhibits section of the LRP report. REA Bulletin 60-9, "Economical Design of Primary Lines for Rural Distribution Systems," should be consulted on system loss rates with correlation drawn between loss tables in that bulletin and historical system losses.

Annual costs that are common to all plans may be omitted from the summary but explanatory notes should be included.

While economic comparison is the primary basis for plan selection, there is no substitute for good judgment based on all available facts. In some instances, indeterminate factors may necessitate the inclusion of an alternative plan to the selected LRP. All work sheets, sketches, maps, etc., used in developing and testing the long-range plan should be retained for future reference. At the discretion of the owner, this may be done by the engineer or it may be turned over to the system staff.

4. Draft Review Conference: Following completion of the exploratory plans and the preliminary selection of the long-range plan by the engineer, a conference should be held to review the rough draft of the long-range plan. The engineer, the system manager, and other appropriate personnel should attend the conference. The REA field engineer and a representative of the power supplier should be invited to attend this conference. Based on the decisions made at this conference, the engineer should prepare a summary planning report. (Appendix IV is a sample form for the "Summary of System Planning Report" which the engineer may elect to use.)

   The owner should review the draft LRP report to verify that the plan:

   a. Is the result of adequate data, engineering analysis and judgment.

   b. Provides sufficient data to serve as a guide for preparation of construction work plans and long-range financial forecasts.

C. Preparation of the Planning Report: The system planning report should present the engineer's analysis of the existing system and the recommended long-range plan including the transition to the long-range system. An alternative plan should be included if there are indeterminate factors. The report should not present detailed analyses of exploratory plans, but, it should contain a summary of each of them. The report should be reasonably brief and concise, covering major points only; however, it must contain sufficient data and summaries of engineering analyses for use in making management studies and policy decisions without reference to the detailed work sheets and data. The superiority of the proposed plan should be indicated and the cost differentials should be shown in dollars. The method of economic analysis should be indicated. When appropriate, small

sketches of the system, or sections of the system, should be used to simplify or replace written descriptions. It is also suggested that summaries of basic data, economic comparisons, cost data, and engineering analyses be presented in the form of tables or graphs.

The engineer should make suggestions to the owner of appropriate items to be standardized, such as, conductor size, substation capacity, etc., and the appropriate sizes.

1. Summaries of Cost Data: New construction and major system improvement items should be tabulated with approximate cost estimates and the approximate year of installation. Groups of other system improvements, including increase in capacity of services and transformers should be tabulated with cost estimates for each year of the plan. Existing plant investment and estimated annual cost of connecting new consumers should also be included. For example, Plan A calls for construction of one new 5 MVA substation each year, etc., Plan B calls for construction of one new 10 MVA substation every two years, etc.

   Most REA borrowers have extensive replacement programs in effect which will continue through the transition to the long-range system. Ordinary replacements are those resulting from rot, corrosion, wear-and-tear, damage, etc., and do not involve an increase in capacity or quality of service. The estimated annual costs of ordinary replacements should be tabulated as a separate item in the cost summary, as should maintenance and system improvements for each exploratory plan. The cost of replacements in connection with system improvements should be included in the investment figures for the system improvements.

   These tabulations of cost data should be broken down by types of facilities such as distribution, transmission and generation, if any. The report should include graphs or tabulations of the projected kW demand as related to time for each substation area or areas which have different levels of usage within a substation area. Management will thus be able to relate investment in facilities to the time of installation for use in preparation of long-range financial forecasts (REA Bulletin 105-5, "Financial Forecast - Electric Distribution Systems," provides information on the data needed in the preparation of such forecasts). A note should be added indicating the month and year on which cost estimates are based. Normally, all cost estimates should be based on present price levels with escalation calculated as estimates of future construction costs are used.

2. Circuit Diagrams: A circuit diagram should be prepared for each major step in the transition including the existing system and for the long-range system. The diagrams should show regulated and unregulated voltage drops resulting from system loading at each step with and without the recommended improvements. Transmission lines of the borrower's system, the power supplier, and

other transmission lines traversing the owner's system should be shown on either the circuit diagram or on a separate transmission diagram.

3. Engineer's Calculations: Detailed calculations upon which engineering analyses and other planning investigations are based need not be included in the system planning report. However, summaries of findings and assumptions used should be included to help management determine the continued validity of and make revisions to the study. Normally, the engineer should retain the calculations and work sheets as long as the system planning contract is in effect. Upon completion or termination of the contract, these files should be made available to the system management.

4. Tables of Contents: Appendix II, "The Suggested Table of Contents for System Planning Report," can be used as a guide in organizing the report and its table of contents. Appendix I is a "Suggested Table of Contents for Analysis of Existing System and Basic Data." The order in which major sections are listed may be changed if it will improve the report. However, care should be taken to see that the requirements of REA Bulletin 20-2, "Electric Loan Policies and Application Procedures," are fulfilled and the presentation demonstrates good practice for engineering reports.

D. Acceptance of Plan: At least five copies of the system planning report should be prepared: two copies are for the owner; two copies are for the REA field engineer; and one copy is retained by the engineer. Other copies may be distributed to the power supplier and the local planning board(s). The system planning report is subject to acceptance by both the owner's management and by REA (as per REA Bulletin 20-2). The owner's board of directors should signify its approval of the report by issuing a resolution. A copy of this resolution should be forwarded to the REA field engineer along with two copies of the report for REA acceptance.

VI. Continuing Planning Activities: Planning for the future is a continuing process. Data should continually be collected - first to check the soundness of the existing plan and later to aid in preparing a new plan. The engineer should assist the owner in establishing methods for obtaining the required data from various operating records and files.

Good system planning requires methods for keeping the plan up to date. It should also provide for construction work plans to implement the transition through timely installation of facilities. The two major phases of continuing planning are:

A. Preparation of Construction Work Plans: A construction work plan should provide a coordinated construction program for two years. It should also provide much of the basic data needed in preparing the system's budget for additional capital investment. REA Bulletin 60-10, "Construction Work Plans, Electric Distribution Systems," provides guidance in preparation, approval, and use of construction work plans. A well prepared construction work plan based on an accepted, up-to-date long-range plan

is generally adequate to demonstrate planning support for a distribution system loan application to REA.

B. Review and Revision of Long-Range Plan: The long-range plan should be reviewed at least each time a work plan is prepared to verify its continued soundness. If the owner finds it necessary, due to unforeseen developments, more frequent reviews may be conducted. The basic data, design criteria, and assumptions used in its preparation should be compared with actual system developments. If the long-range plan proves to be sound, a letter or memo should be prepared by the reviewer and inserted in the construction work plan. If a revision to the plan is deemed necessary, the revision should be a separate concise report, with an appropriate title, properly dated and with the necessary references to the parts of the existing report that are being revised. The distribution of copies of revisions should be the same as for the original system planning report. Long-range plan revisions are subject to approval by the owner's board of directors and acceptance of the original long-range plan (see paragraph V.D. "Acceptance of Plan").

Review (and revision as necessary) of the long-range plan will extend its useful life and indicate the need for a new plan when revisions are no longer adequate. Many things can happen to necessitate revision or replacement of the long-range plan. Loads may develop faster than projected in some areas and slower than projected in other areas; power suppliers may change their plans; it may be necessary to provide for extensive transmission system construction; necessary rights-of-way may not be obtainable; laws and ordinances may change (such as requirements for underground line construction); and technological developments may occur. Any one of these may be reason for adjustment or replacement of the plan. Even if no major changes are needed, as numerous minor revisions are made consideration should be given more and more to a new long-range plan. The cost of planning activities should be considered as an investment which can prevent financial loss. Thus long-range planning may be one of the biggest bargains available to electric distribution system management.

Joe S. Zoller

JOE S. ZOLLER
Assistant Administrator - Electric

Attachments:
- Appendix I
- Appendix II
- Appendix III
- Appendix IV

Index:
DESIGN SYSTEM
System Planning Guide
SYSTEM PLANNING
Guide

APPENDIX I

Suggested Table of Contents
for
Analysis of Existing System and Basic Data

A. Introduction

B. Purpose of Analysis

C. Summary of Analysis, Conclusions and Recommendations

D. System Growth Patterns
    1. Land Use Plans
    2. Load Density Projections

E. Capacity of Existing System
    1. Service to Present Loads
    2. Service to Future Loads
    3. System Performance
        a. Voltage Levels
        b. Service Reliability
        c. Energy Losses
        d. Operating Expenses

F. Environmentally Sensitive Areas

G. Adequacy of Basic Data

H. Appendix
    1. Tabulation of Basic Data
    2. Maps and Circuit Diagrams
    3. Copies of Pertinent Correspondence
    4. Other Exhibits

APPENDIX II

Suggested Table of Contents for System Planning Report

I. Introduction

II. Purpose of Report

III. Summary of Report, Conclusions and Recommendations

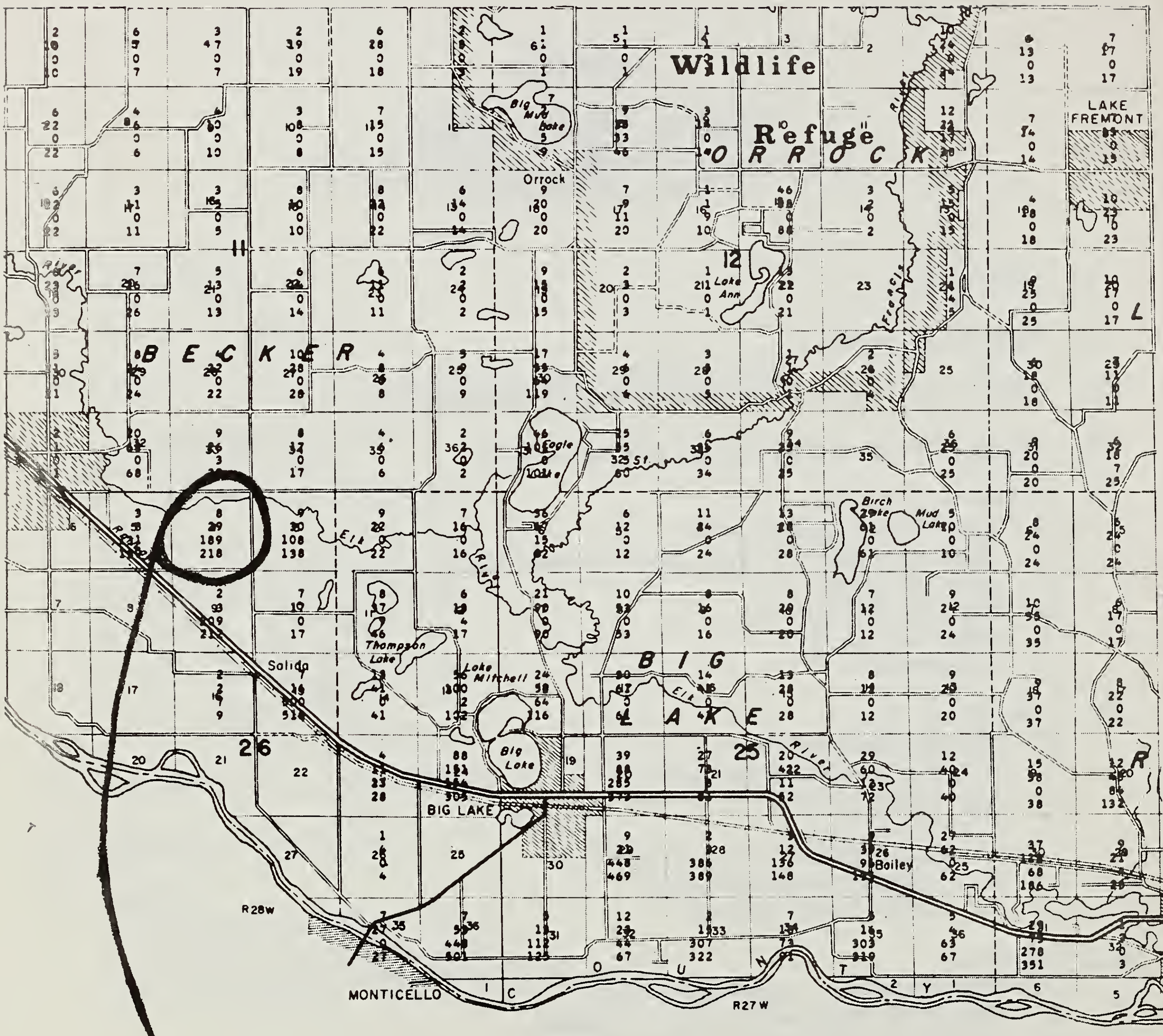
IV. Analysis of Existing System and Basic Data

V. Planning Criteria
   - A. Long Range Demand Level
   - B. Area Load Density and Growth Potential
   - C. Special Loads
   - D. Service Reliability
   - E. Other Criteria
   - F. Assumptions

VI. Long-Range Plan
   - A. The Recommended Plan
   - B. Alternate Recommendations
   - C. Exploratory Plans
   - D. Plan Selection
     1. Examination of the Transition
     2. Economic Justification
     3. Other Justification

VII. Exhibits
   - A. Tabulations of Supporting Data
   - B. Sketches, Maps and Circuit Diagrams
   - C. Copies of Pertinent Correspondence
   - D. Other Exhibits

APPENDIX III
Sample Map: System Growth Patterns



8	NUMBER OF RESIDENTIAL CONSUMERS
29	KW DEMAND-RESIDENTIAL CONSUMERS
189	KW DEMAND-COMBINED COMMERCIAL AND INDUSTRIAL CONSUMERS
218	KW DEMAND-TOTAL

APPENDIX IV
SAMPLE FORM

SUMMARY OF SYSTEM PLANNING REPORT	SYSTEM DESIGNATION	DATE PLANNING REPORT COMPLETED
	PLANNING ENGINEER	

PART I GENERAL DATA

ITEMS	2. LINE MILES		3. NO. OF CONSUMERS		TOTAL SYSTEM LOAD *(kW)*	TOTAL SPECIAL LOADS *(kW)*	TOTAL YEARLY SALES kWh	7. PAST PEAK LOAD		DESIGN LOAD kWh/CONS. /MO. PEAK MO.
	TRANS.	DISTR.	ALL TYPES *(Includes special loads)*	SPECIAL LOADS				kWh/CONS. /MO.	DATE	
1.	a.	b.	a.	b.	4.	5.	6.	a.	b.	8.
PRESENT SYSTEM AS OF										
LONG RANGE PLAN										

PART II LINE MILES

ITEMS	2. DISTRIBUTION				3. TRANSMISSION			
1.	12.5/7.2 kV a.	24.9/14.4 kV b.	______kV c.	______kV d.	34.5 kV a.	69 kV b.	______kV c.	______kV d.
PRESENT SYSTEM AS OF								
LONG RANGE PLAN								

PART III SUBSTATIONS AND METERING POINTS

NAME OR LOCATION*	POWER SUPPLIER	3. PRESENT SYSTEM			4. LONG RANGE PLAN		
		kVA	kV PRIMARY	kV SECONDARY	kVA	kV PRIMARY	kV SECONDARY
1.	2.	a.	b.	c.	a.	b.	c.

PART IV INVESTMENT IN PLANT *(Dollars)*

ITEMS 1.	TRANSMISSION LINES 2.	ALL SUBSTATIONS 3.	DISTR. TRANSFORMERS, METERS & SERVICES 4.	ALL OTHER DISTR. FACILITIES 5.	TOTAL T & D PLANT 6.	GENERAL & PROD. PLANT 7.
PRESENT SYSTEM AS OF						
LONG RANGE PLAN						

NOTED

DATE	SIGNATURE	DATE	SIGNATURE
	REA FIELD ENGINEER		AREA MANAGER

**Include those furnished by Power Supplier and designate with asterisk.*

APPENDIX V

List of References

1. REA Bulletin 20-2, Electric Loan Policies and Application Procedures
2. REA Bulletin 40-4, Guide for Mapping and Location Numbering of Electric Distribution Systems
3. REA Bulletin 40-6, Construction Methods and Purchase of Materials and Equipment
4. REA Bulletin 41-1, Engineering Services for Electric Borrowers
5. REA Bulletin 45-1, Guide for Making Voltage Drop Calculations
6. REA Bulletin 45-4, Distribution System Energy Losses
7. REA Bulletin 60-1, Circuit Diagrams, Electrical Data Sheets and Other Drawings for Systems of Electric Borrowers
8. REA Bulletin 60-7, Service Reliability
9. REA Bulletin 60-9, Economical Design of Primary Lines for Rural Distribution Systems
10. REA Bulletin 60-10, Construction Work Plans, Electric Distribution Systems
11. REA Bulletin 60-13, Conversion of 7.2/12.5 kV to 14.4/24.9 kV Distribution
12. REA Bulletin 61-2, Guide for Making A Sectionalizing Study on Rural Electric Systems
13. REA Bulletin 61-3, Underground Rural Distribution
14. REA Bulletin 61-15, Selection and Application of Underground Rural Distribution Cable
15. REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines*
16. REA Bulletin 62-5, Electrical Characteristics of REA Alternating Current Transmission Line Designs
17. REA Bulletin 62-6, An Overview of Transmission System Studies
18. REA Bulletin 65-1, Design Guide for Rural Substations
19. REA Bulletin 105-5, Financial Forecast - Electric Distribution Systems
20. REA Bulletin 112-6, Large Power Rates and Contracts
21. REA Bulletin 161-5, Electric System Review and Evaluation
22. REA Bulletin 161-7, Guide for Making Voltage Measurements on Rural Distribution Systems
23. REA Bulletin 161-8, Voltage and Current Investigations
24. REA Bulletin 161-9, Guide for Making Current Measurements on Rural Distribution Systems
25. REA Bulletin 169-1, The Application of Shunt Capacitors to the Rural Electric System
26. REA Bulletin 169-4, Voltage Levels on Rural Distribution Systems
27. REA Bulletin 169-27, Voltage Regulator Application on Rural Distribution Systems
28. REA Form 215(5-67), Engineering Service Contract-System Planning

*Formerly titled "Transmission Line Manual"

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